TARA OCEANS

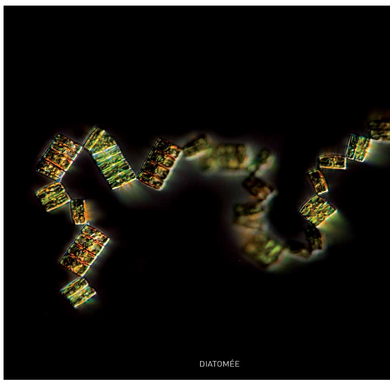
TARA OCEANS EXPEDITION 2009 - 2013:

EXPLORING THE INVISIBLE

The ocean is a very complex ecosystem, like a living organism. Knowing a patient's temperature is essential, but without taking a blood sample, the diagnosis is incomplete. In the past, oceanographers have measured the physico-chemical parameters of the ocean, with the *Tara Oceans* expedition, we entered a new era: the analysis of its biological parameters.
The schooner *Tara* sailed for three and a half years across all of the world's oceans on a novel mission: the planetary study of marine plankton. Its invisible and largely unexplored biodiversity is a crucial marker of the state of our planet and its climate system. The *Tara Oceans* expedition is the first scientific endeavour to produce such an incredible overview of the microscopic world that plays a key role in supporting life on Earth.

What if the clues to understanding the oceanic ecosystem were invisible?

The word plankton comes from the Greek word "planktos", which means "to wander". Plankton refers to all of the organisms that are carried by marine currents. Most of them are microscopic, including tiny viruses, bacteria, micro-algae and krill.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TARA OCEANS

N°5

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tara EXPEDITIONS

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TARA OCEANS

agnès b.

Destination océans

Tara s'engage dans une nouvelle mission planétaire : une expédition scientifique de trois ans. La goélette va sillonner les océans du globe pour étudier les écosystèmes marins, indispensables à la vie sur Terre.

La goélette va parcourir 150 000 kms de septembre 2009 à novembre 2012. © J.Girardot/Fonds Tara

TARA OCEANS,

A REVOLUTIONARY EXPEDITION

Two men are at the origin of this historical adventure, a public-private partnership that combines academic research with the know-how of a non-profit foundation:

– Étienne Bourgois, president of the *Tara Expeditions Foundation* and CEO of *agnès b.*

– Éric Karsenti, Visiting Group Leader at EMBL and CNRS, co-director of *Tara Oceans*, and CNRS Gold Medalist in 2015.

ERIC KARSENTI

"We were going to discover thousands of marine species and, thanks to genomics, investigate how these species are linked together. We were going to return to, 200 years after Darwin, the extensive study of marine evolution."

ETIENNE BOURGOIS

"From the beginning of the expedition, we decided to make the collected data accessible to all. This had to be more than just a European mission. We were listening to experts from all over the world."

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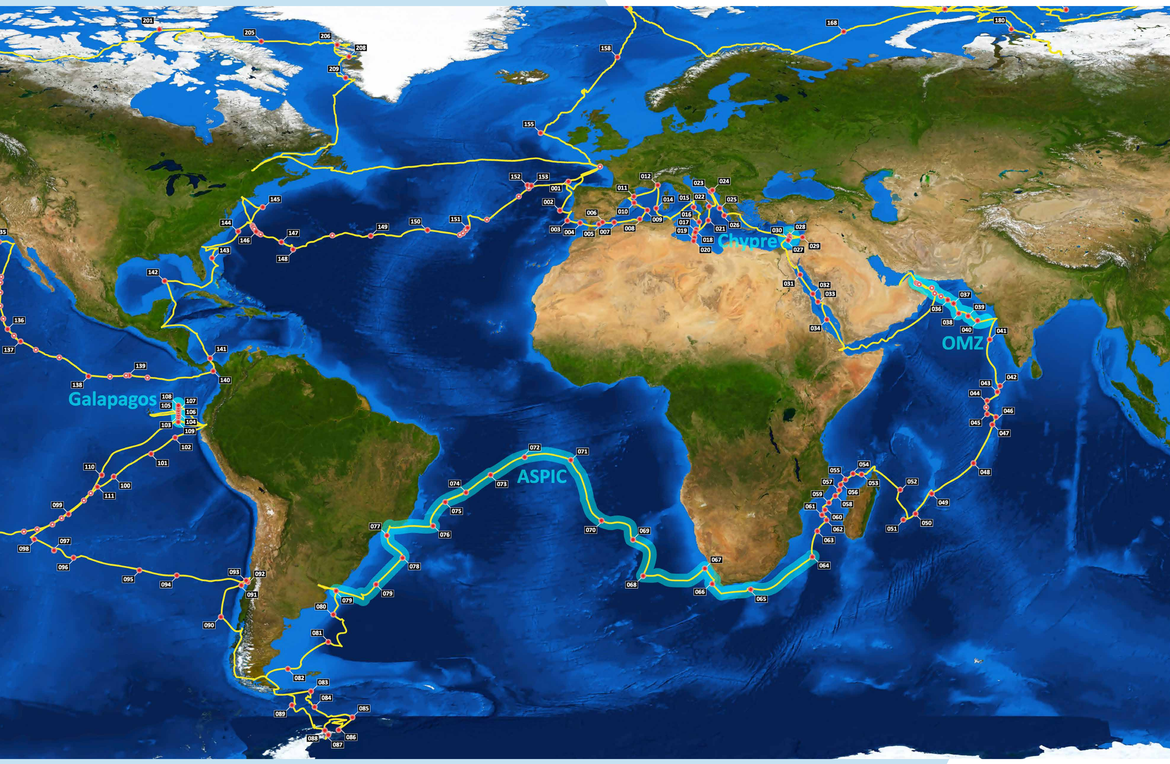
TARA OCEANS,

150,000 KILOMETERS ACROSS ALL OCEANS OF THE GLOBE

The expedition mobilized more than 200 people of 35 nationalities



90 CREW MEMBERS
160 SCIENTISTS
40 NATIONALITIES
23 LABORATORIES INVOLVED

60 STOPOVERS
40 COUNTRIES
1 140 DAYS OF EXPEDITION
210 SAMPLING STATIONS
35 000 SAMPLES COLLECTED

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THE OCEAN

OUR PLANET'S BIGGEST FOREST

At the origin of life

Plankton, atmosphere and climate are intimately linked. Their relationships are at the origin of the first traces of life on the planet. More than 3 billion years ago, some planktonic micro-organisms capable of photosynthesis, called cyanobacteria, began to inject oxygen into a primitive atmosphere which had none.

Reservoir of life

95 % of the ocean's biodiversity is plankton. Planktonic microorganisms are essential for the global food supply because they constitute the first link in the marine food chain.

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THE OCEAN,

AN ESSENTIAL ACTOR IN GLOBAL CLIMATE EQUILIBRIUM

Thermostat of the planet: The ocean stores and redistributes enormous quantities of heat thanks to marine currents, guaranteeing its better distribution around the globe.

The ocean warms and cools very slowly and can store up to 1,000 times more heat than the atmosphere. This immense body of water therefore plays a key role in global climate regulation.

Carbon pump: Covering more than 70% of the Earth's surface, the ocean serves as a carbon pump. By means of photosynthesis, marine phytoplankton absorbs about one third of the carbon dioxide emitted into the atmosphere each year by humans and produces more than half of the oxygen we breathe. By absorbing this greenhouse gas, the ocean reduces heat produced by human activity and keeps the planet habitable.

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THE OCEAN UNDER STRESS

Formerly a relatively stable environment, the ocean is now changing profoundly. Since the beginning of the Industrial Revolution, the ocean has absorbed 93% of the excess heat, more than a quarter of our carbon dioxide emissions and nearly all of the fresh water from melting ice. The ocean's physical and chemical parameters have thus been altered in a very short period of time, and planktonic organisms are seeing their habitats change at an unprecedented pace.

Temperature increase

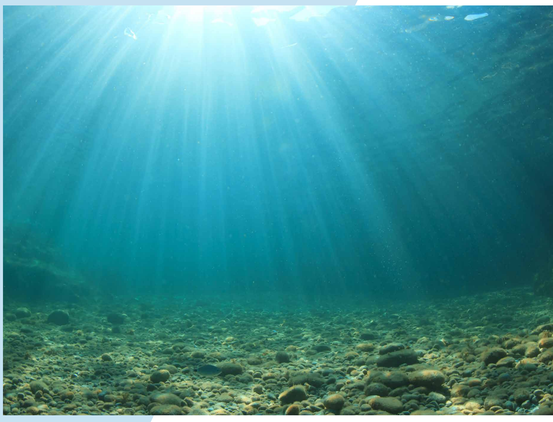
More than 90% of heat produced by the greenhouse effect has already been absorbed by the ocean, whose average temperature is continuously increasing. The consequences will be major: migration of species, perturbation of oxygen exchanges and irreversible impact on coral reefs.

Ocean acidification

The increasing quantity of carbon dioxide dissolved in seawater results in its increased acidity. This phenomenon could lead to major disturbances, in particular the ability of some organisms to manufacture their calcified skeletons and shells, as well as jeopardising a large number of ecosystems.

Rising seawater levels

The rise in sea levels results from the combination of warming, which increases the ocean's volume, and the influx of freshwater due to melting ice. By 2050, more than 250 million people could become climate migrants.



Oxygen depletion in the ocean

Some areas of the ocean contain very little or no oxygen. Global warming will worsen this phenomenon and these deoxygenated areas, called "dead zones", will expand.

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THE OCEAN,

AN UNKNOWN FUTURE

As the climate system rapidly shifts, acquiring a more complete knowledge of the ocean and attempting to predict its transformations became more urgent.

Plankton, an invisible and little known ecosystem

The central role of the planktonic ecosystem in the regulation of our planet's climate has been amply demonstrated. Plankton is one of the keys to comprehending climate change. However, its diversity, functioning and its vulnerabilities are little understood, which prevents us from foreseeing plankton's response and evolution in the face of global changes.

"The data collected by Tara is crucial because any variation in plankton composition can have an impact on the planet's balance of gases."

Éric Karsenti, co-scientific director of *Tara Oceans*, Visiting Group Leader at EMBL

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TARA
OCEANS

TARA OCEANS

DISCOVERING THE HIDDEN FACE OF THE OCEAN

The oceans are full of life: each litre of sea water contains between 10 and 100 billion planktonic microorganisms – viruses, bacteria, phytoplankton and zooplankton.

Tara Oceans set out to discover the curious beings whose uncertain future will greatly influence our planet's changing climate.

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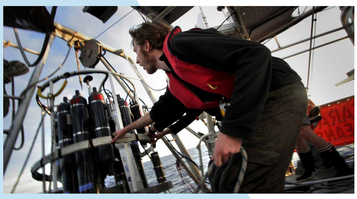
L'OCÉANOGRAPHIE "MADE IN TARA"

The mission of Tara Oceans: to combine genetics with the study of classic oceanography.

1./ The aft deck of *Tara* at the start of a scientific station. This is when the schooner will carry out sampling while stationary over an area of interest identified using satellite data.



2./ The scientists dispatch the rosette , a specially designed sampling and recording device, to carry out physical and chemical measurements. This initial dive records the characteristics of the water column under the boat.

3./ At the same time, the peristaltic pump is rigged on the starboard deck and samples up to 50 litres of sea water per minute without damaging the organisms.

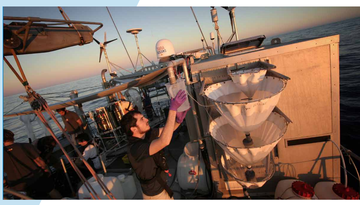
4./ From the aft deck, nets with different meshes are immersed to various depths until 500 m. Their function is to collect plankton.

5./ The water collected by the pump is taken to the wet laboratory. Part of it is then filtered through various devices that retain the plankton in membranes.

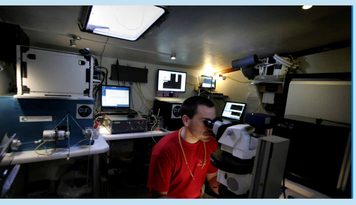
6./ The rest of the water is filtered through a system of superimposed nets with different meshes before being filtered again in the wet laboratory.

7./ On the aft deck the rosette is hoisted up. The programmed opening of its bottles ensures that water samples are taken at different depths, down to 2,000 m.

8./ Like the water pumped on the surface, the water collected at lower depths by the rosette will be filtered, chemically fixed and sampled according to the particular types of organisms being studied.



9./ Certain methods of sample preparation require liquid nitrogen. Once the various types of samples have been prepared they are stored in refrigerators situated in the forward hold.



10./ In the dry laboratory some instruments collect data continuously while others are used to measure and visualise specimens drawn from the marine biomass, many of which are unknown to us.

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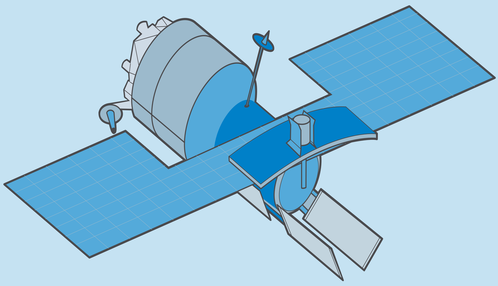
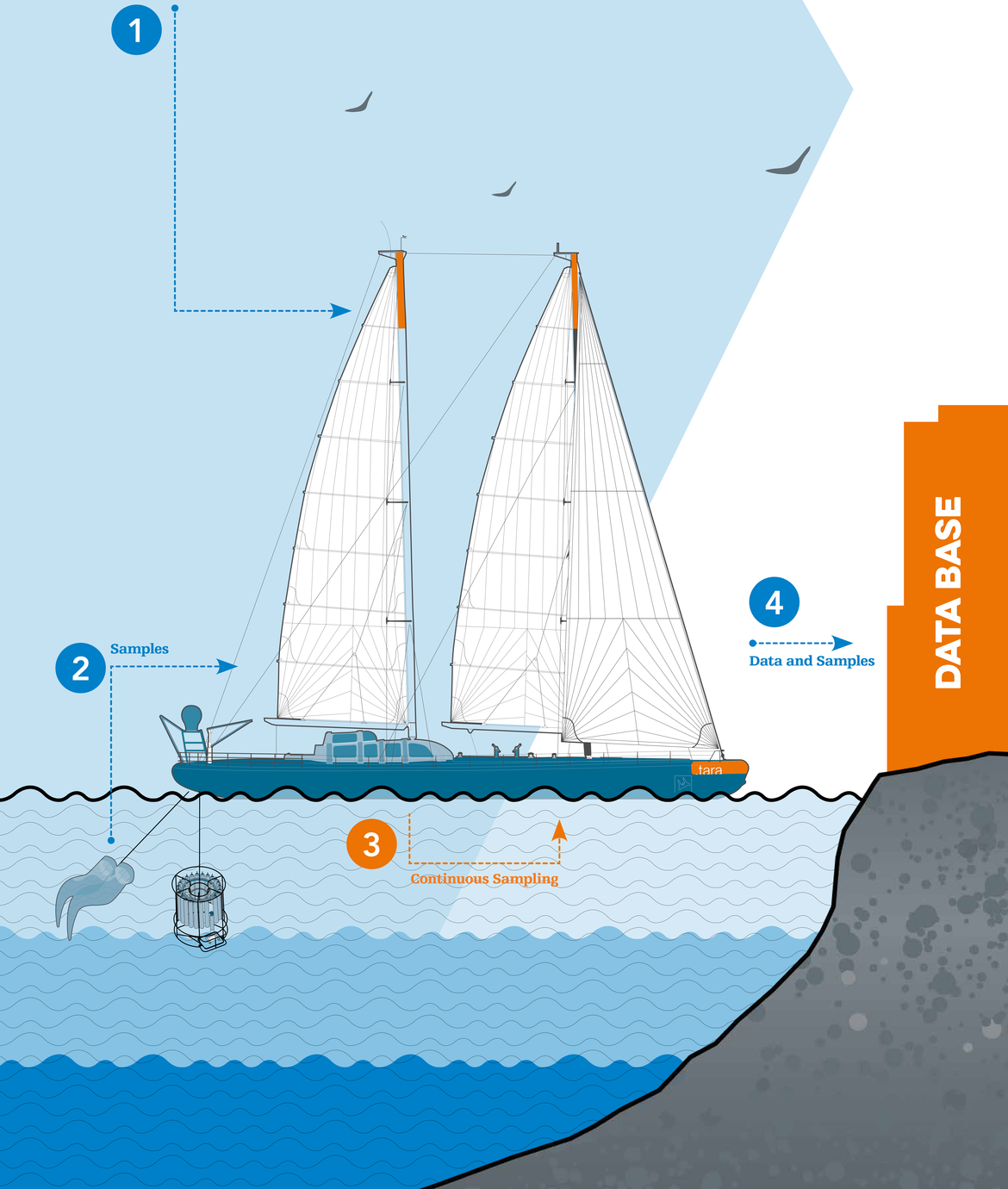
HOW THE DATA AND SAMPLES TRAVEL

STEPS

1 Locate → 2 Sample → 3 Analyse aboard → 4 Send data

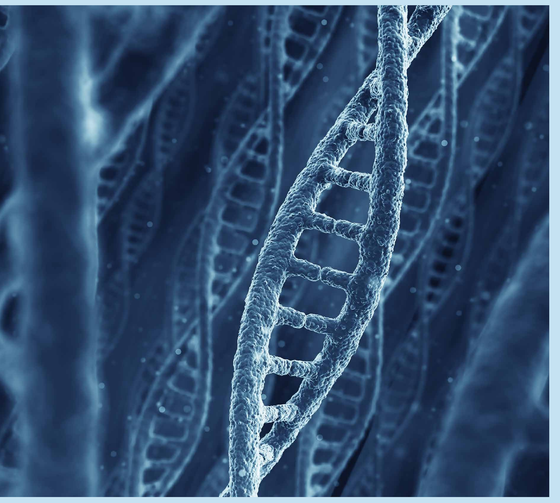




TARA OCEANS

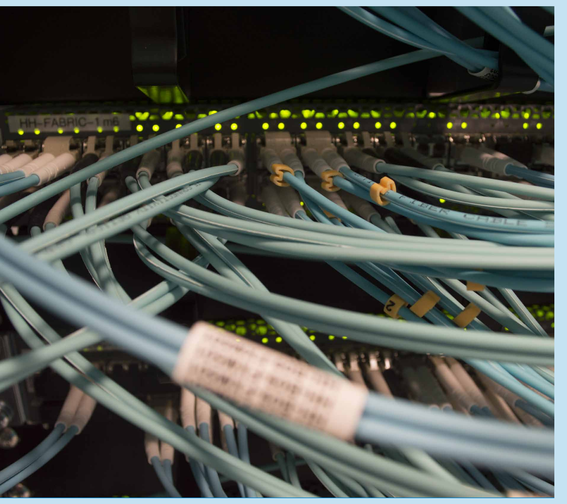
FROM SAMPLES TO DATABASE

After being collected and temporarily stored aboard *Tara*, samples are shipped to various partner laboratories where they are analysed. Using state-of-the art techniques of DNA sequencing, microscopic imaging and bioinformatics, some of the samples collected during the *Tara Oceans* expedition have already been examined.



Sequencing

Planktonic microorganisms are extremely abundant and diverse. To capture their complexity, scientists decipher their genes directly. To do this, they extract the DNA. Reading genomes allows them to identify specific organisms, know their function in the ecosystem and determine their ability to adapt to environmental changes.



Storage

The data is classified into 2 groups and stored accordingly: raw genetic sequences are stored on the *European Nucleotide Archive* (ENA) and environmental data is stored on *Tara Ocean's* sample registry, called *PANGAEA*.

Bioinformatic analysis

The European Bioinformatics Institute (EMBL-EBI), using complex analytical methods, is then able to link all of the biological, genetic and environmental data to help scientists understand the functioning of the planktonic ecosystem.

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TARA OCEANS REVEALS AN UNKNOWN WORLD

In May 2015, the largest plankton study ever done in all of the world's oceans – the *Tara Oceans* expedition – published its first results in 5 scientific articles in the journal *Science.*
In all there have been more than 120 publications in various scientific journals. These results are transforming our understanding of the marine ecosystem.

"Data from Tara Oceans will help build predictive models of ecosystem evolution as a function of temperature. Now we need to extrapolate these predictions to all organisms in order to have an accurate vision of the future and the impact of climate change."

ERIC KARSENTI – Visiting Group Leader at EMBL and CNRS; director of Tara Oceans; CNRS Gold Medal winner in 2015

EXPEDITION
35,000 samples collected

ANALYSIS
Only 30% analysed to date

09/2008
Preparation and launch of the Tara Oceans expedition

03/2013
Launch of OCEANOMICS®

12/2013
Return of the Tara Oceans expedition

05/2015
1st scientific results of Tara Oceans presented on the cover of Science – 5 articles

2016
5 Publications of new Tara Oceans results in the journal Nature

2016
5 Publications of new Tara Oceans results in the journal PNAS

2017 > 2030
Continuing analysis of the Tara Oceans data

Futures Investments Program – Oceanomics, 2018

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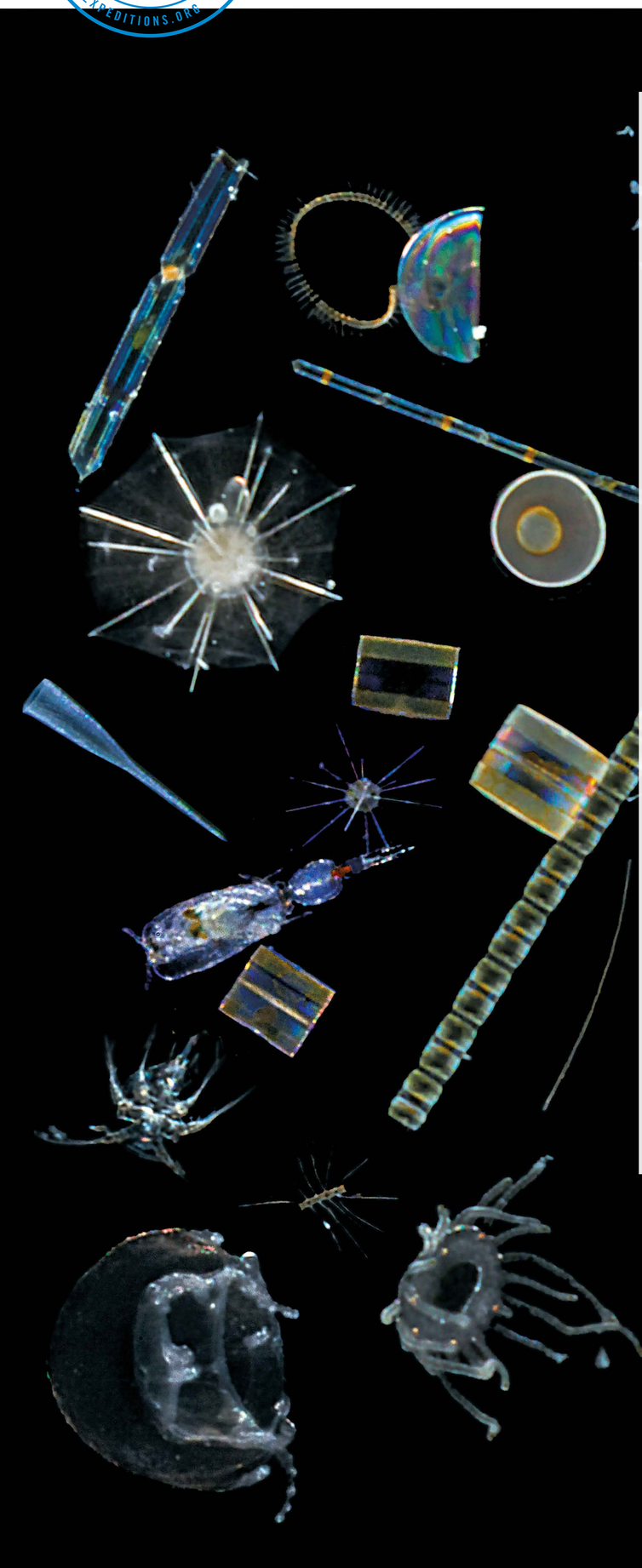

TARA OCEANS

FIRST CATALOGUE OF THE PLANKTONIC WORLD

The first analyses of samples collected during the *Tara Oceans* expedition revealed, above all, the extent of our ignorance of the planktonic world. Comprised of a great diversity of organisms, mostly invisible and unicellular, plankton is complex to study but fundamental to understand. *Tara Oceans* scientists have sequenced 40 million new genes, corresponding to about 130,000 new genetic species types. This data, gathered into easily accessible databases, will provide researchers with a nearly exhaustive catalogue of marine plankton.

Oceanographers now have a new view of this complex ecosystem, as if they had discovered the missing pieces of a puzzle. The picture they are working to reveal will help us better understand the distribution, evolution, and adaptation of plankton.

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PLANKTON'S SOCIAL NETWORK REVEALED

Planktonic organisms are in constant interaction. Some collaborate and engage in symbiosis with a specific partner, others have relationships of competition, predation or parasitism. In effect, the interactions between planktonic species form a huge social network.

The study of *Tara Oceans'* data makes it possible to map this network of interactions between organisms for the first time. Because environmental parameters are essential drivers for the distribution and composition of plankton, analyses have demonstrated the fundamental and underestimated role of interdependent relationships within this ecosystem. Parasitism seems to be the most widespread type of interaction, indicating that parasitic organisms play a major ecological role, the nature and extent of which still needs to be clarified. Interactions among planktonic organisms are more common than exclusions, suggesting that cooperation is more important than competition.

This multitude and diversity of interactions directly influences the activity of plankton, and therefore its role as a climate regulator.

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PLANKTON UNDER SURVEILLANCE: THE IMPORTANCE OF TEMPERATURE

Among the environmental factors that govern composition and distribution of plankton in the ocean, *Tara Oceans* scientists showed that temperature is the determining factor for oceanic zones exposed to light. This result implies that global warming could have a strong impact on the microbial communities that live in this zone. They are invisible to the naked eye, and yet their photosynthetic activity is at the base of marine food chains. *Tara Oceans'* data is an important step in assessing these changes. It acts as a "ground zero" of the ocean, a baseline against which upheavals in the planktonic world and in the entire oceanic ecosystem can be evaluated.

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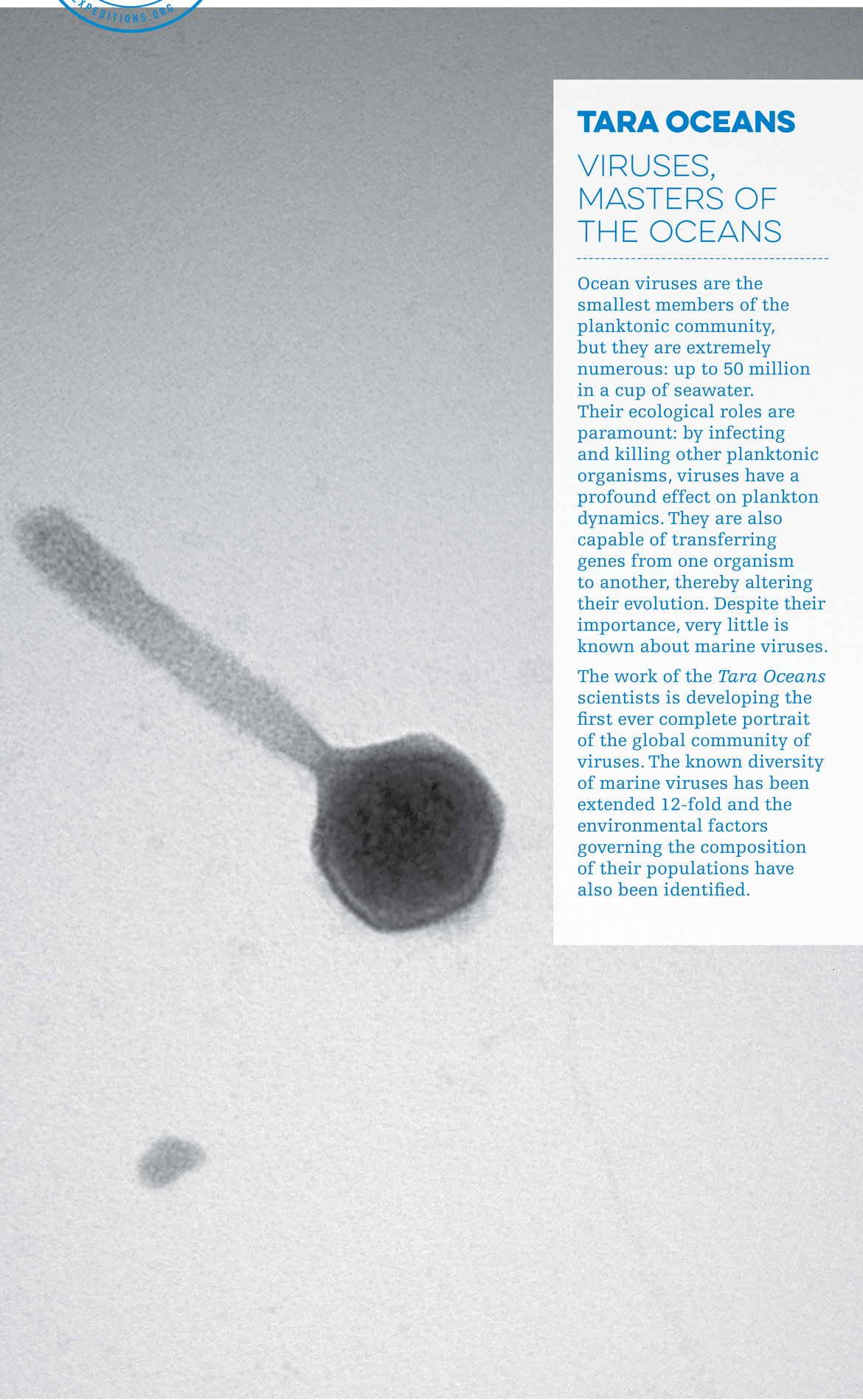

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VIRUSES, MASTERS OF THE OCEANS

Ocean viruses are the smallest members of the planktonic community, but they are extremely numerous: up to 50 million in a cup of seawater. Their ecological roles are paramount: by infecting and killing other planktonic organisms, viruses have a profound effect on plankton dynamics. They are also capable of transferring genes from one organism to another, thereby altering their evolution. Despite their importance, very little is known about marine viruses.

The work of the *Tara Oceans* scientists is developing the first ever complete portrait of the global community of viruses. The known diversity of marine viruses has been extended 12-fold and the environmental factors governing the composition of their populations have also been identified.

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RHIZARIA, OVERLOOKED GIANTS

One group of unicellular zooplankton in particular drew the attention of the scientists : Rhizaria. These organisms are very fragile and most often were found crushed in scientists' plankton nets. As a consequence, their presence had largely gone unnoticed until now.

By observing Rhizaria directly in their environment with an underwater camera, the *Tara Oceans* researchers found them to be surprisingly numerous, representing about 5% of the total mass of marine organisms – from viruses to whales! This indicates that the role of Rhizaria, particularly in carbon sequestration, has been largely underestimated. They appear to be an important link in the ocean ecosystem.

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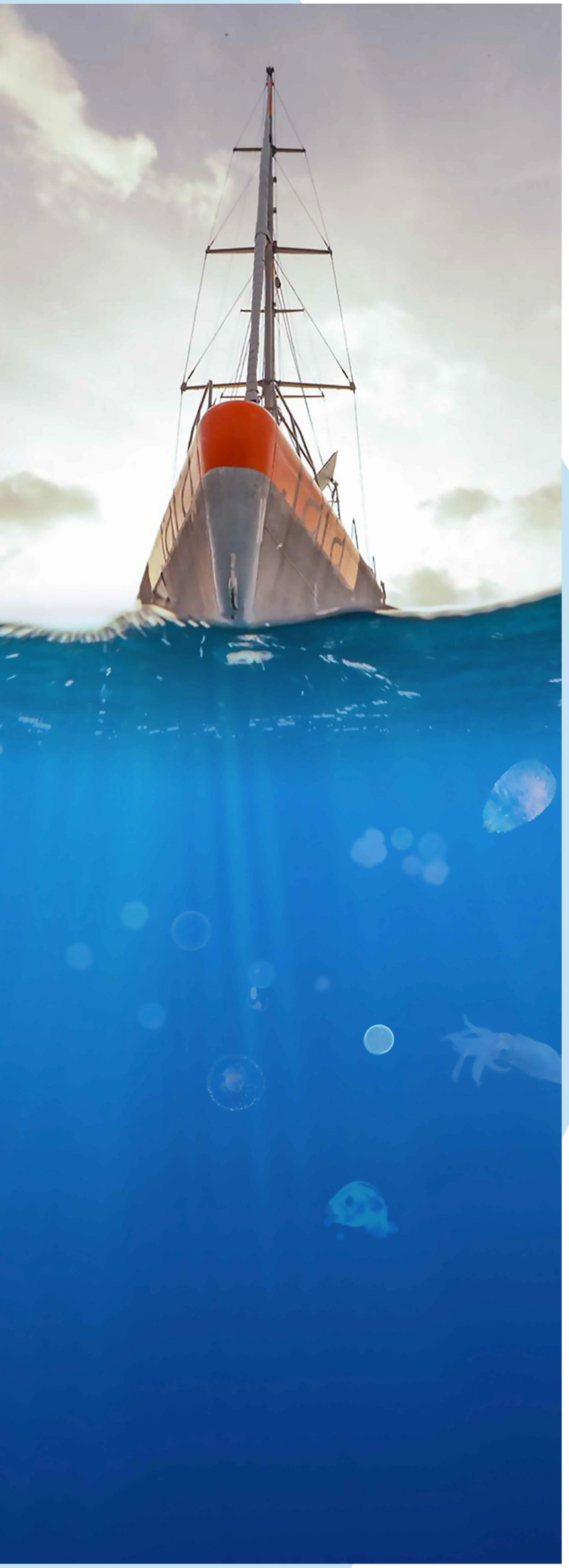

A SHARED TREASURE

The ocean has no real boundaries besides those imagined by humankind. Under our joint responsibility, the treasure trove of data collected during the *Tara Oceans* expedition will broaden understanding and encourage preservation of the ocean. With this new knowledge, we will also be able to more accurately predict how the ocean might change in the future. This is a treasure to be shared, the *raison d'être* of the *Tara Expeditions Foundation*.

A COMMITTED PHILOSOPHY OF RESEARCH

An interdisciplinary research team

The scientific consortium of *Tara Oceans* has brought together 21 specialtists: geneticists, physicists, chemists, bio-informaticians and experts in modelling. This interdisciplinarity allows us to understand the ocean in a holistic way – from molecule to ecosystem.

... that shares data with the entire scientific community...

Data collected during the *Tara Oceans* expedition is accessible to all and free of charge. Anyone with an internet connection can access it by logging on to the EMBL-EBI website.

... and gets developing countries on board.

Beyond sharing the collected data, we must ensure that everyone has the capacity to use it. The *Tara Expeditions Foundation* and the scientific consortium are currently working in collaboration with developing countries to train a future generation of experts.

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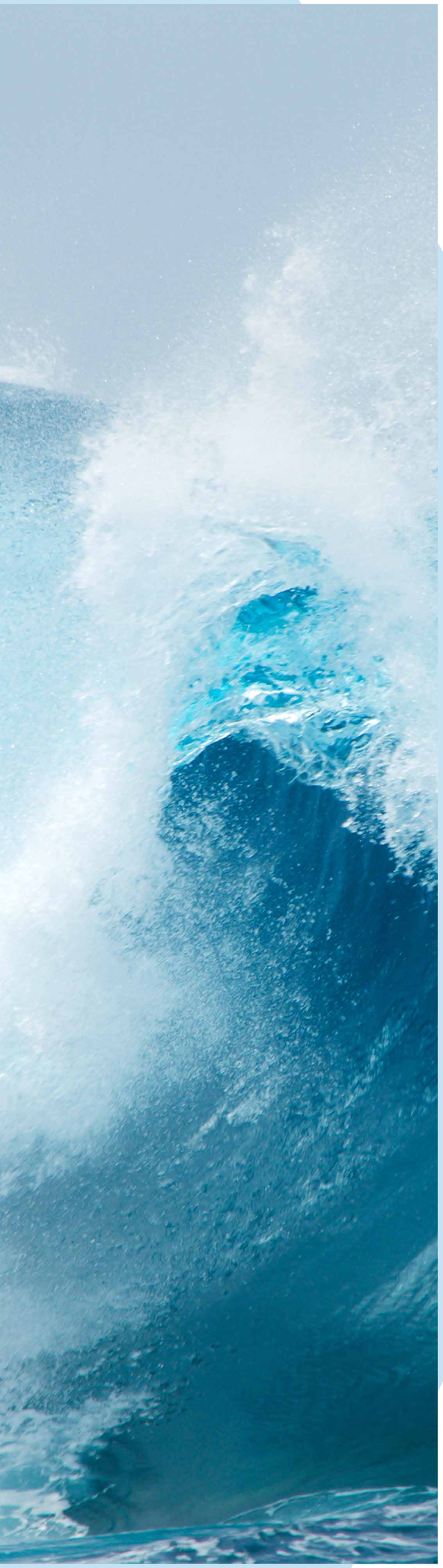

MAKING THE OCEAN

A COMMON RESPONSIBILITY

Unpublished data collected from the *Tara Oceans* expedition is available to everyone, but only a handful of countries currently have the capacity to exploit it.

In partnership with the *French Global Environment Fund* (FFEM), the Tara Expeditions Foundation launched the Oceanic Plankton, Climate and Development project in 2016. It fosters the involvement of emerging and developing countries in cutting-edge marine science research.

Six young scientists from these countries are currently being trained in *Tara Oceans* partner laboratories in Europe, at the CEA, ENS, CNRS and EMBL. These young scientists are gaining skills that they can then apply and teach.

Strengthening the research capacities of these countries, which often depend heavily on the good health of the marine ecosystem, will enable them to fully participate in the protection and sustainable exploitation of the oceans, as well as take part in climate negotiations.

NORTH AND SOUTH

A NEW GENERATION OF OCEANOGRAPHERS

"If we want a sustainable ocean, we must first understand how it works."
Juan Pierella Karlusich, geneticist, Argentina

"This project is an opportunity to acquire expertise that will help me advance my country towards a better management of fishing and understanding of climate."
Dodji Yawouvi Soviadan, physicist, Togo

"Researchers working on Tara Oceans data collaborate a lot with each other."
Janaina Rigonato, geneticist, Brazil

"The potential of Tara Oceans data lies in the overall scale of sampling. Usually we only have access to certain parts of the ocean."
Alejandro Murillo, microbiologist, Chile

FFEM FONDS FRANÇAIS POUR L'ENVIRONNEMENT MONDIAL

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A WORLD OF KNOWLEDGE

STILL TO DISCOVER

Only one third of the data collected during the *Tara Oceans* expedition has been analyzed to date, so the potential for discovery remains immense. Modelling of marine ecosystem evolution will continue over the next 15 years.

The first results essentially describe the diversity of planktonic organisms while expanding the inventory of this population, particularly in specific regions such as the Arctic Ocean.
Once the mysteries of plankton have been elucidated, and their functioning and capacity to adapt are better understood, scientists will be able to improve their biological models. At present, these models are too imprecise to predict in more detail the future health of the oceans and all that depends on it: climate, distribution of marine resources and the state of fish stocks.

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RAISING AWARENESS

INCREASED UNDERSTANDING TO PROTECT THE OCEAN

The *Tara Expeditions Foundation* acts in many ways to strengthen the environmental awareness of the general public and young people.

Adventure aboard the schooner *Tara* is a tremendous spring-board to raise awareness among the general public and highlight today's environmental challenges. The message sent by Tara is disseminated all over the planet to strengthen environmental awareness, mainly towards younger generations.

Throughout the world and in collaboration with schools, *Tara Oceans* works to stimulate the curiosity of children and give them a taste for science by explaining the scientific method and introducing them to state-of-the-art tools for observing our planet's oceans.

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JOIN US

IN TAKING ACTION

Since 2003, the *Tara Expedition Foundation* has been working for the environment and scientific research

The *Tara Expedition Foundation* is pursuing more than ever the development of an open, innovative science of the ocean – one that will enable us to understand this ecosystem that is so crucial for the planet's equilibrium.

Today the *Tara Expeditions Foundation* continues and intensifies its action:

-by preparing a new expedition to the Arctic for an unprecedented study of the marine polar ecosystem

- by continuing actions, especially with the UN, to establish a governance of the ocean

-by cooperating with researchers in developing countries to share knowledge

We need the help of everyone to move forward. The *Tara Expedition Foundation* functions thanks to the generosity of our donors. Every gift counts and allows us to continue.

Give your support to the *Tara Expeditions Foundation*:
www.oceans.taraexpeditions.org

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THE EXHIBITION TARA OCEANS - EXPLORING THE INVISIBLE

IS BROUGHT TO YOU BY THE TARA EXPEDITIONS FOUNDATION

Etienne Bourgois,
President and co-founder of *Tara Expeditions*

Romain Troublé,
Executive director of the *Tara Expeditions Foundation*

PROJECT DIRECTOR

Myriam Thomas – Commitment

GRAPHICS

Matthieu Boyé – La Niak
Valentine Petit-Morin – Le design c'est l'aventure

MUSEOGRAPHY-ICONOGRAPHY

Myriam Thomas – Commitment
Elodie Bernollin – Tara Expeditions Foundation
Chris Bowler – ENS
Margaux Gaubert – Tara Expeditions Foundation

TRANSLATION

Dana Sardet, Patrick Chang

SCIENTIFIC PARTNER FOR CREATING THE EXHIBITION

EMBL

CREDITS/ PHOTOS OF MICRO-ORGANISMS

Exploring the hidden side of the ocean
Plankton mandala by Christian & Noe Sardet (Plankton Chronicles)

The plankton social network unveiled
Drawing by Christian Sardet, from article in the journal Science

Tara Oceans expedition 2009 - 2013: Exploring the invisible/
The Ocean under pressure/ The first catalog of a microscopic world
Christian Sardet (Plankton Chronicles)

Viruses, Masters of the Oceans
Transmission electron micrograph by Jennifer Brum and Matthew Sullivan, Ohio State University

OTHER PHOTO CREDITS

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